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CERTIFICATE

This certificate is issued in support of an application for Patent registration in a country outside New Zealand pursuant to the Patents Act 1953 and the Regulations thereunder.

I hereby certify that annexed is a true copy of the Provisional Specification as filed on 28 July 2003 with an application for Letters Patent number 527244 made by The University of Waikato.

Dated 2 August 2004.

Neville Harris

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Commissioner of Patents, Trade Marks and Designs

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James & Wells ref: 122329/16

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PROVISIONAL SPECIFICATION

IMPROVED SYSTEM AND COMPUTER SOFTWARE FOR MODELLING ENERGY CONSUMPTION

I/WE The University of Waikato, a New Zealand company of Gate 5, Hillcrest Road (no number), Hamilton, New Zealand

do hereby declare this invention to be described in the following statement:

IMPROVED SYSTEM AND COMPUTER SOFTWARE FOR MODELLING ENERGY CONSUMPTION

TECHNICAL FIELD

This invention relates to an improved system, apparatus, software and/or a method of modelling the energy consumption of a process or cluster of processes. In particular, the present invention may be provided through computer software adapted to track particular resource streams employed within a process or cluster of processes and to calculate energy consumption values for the specific process or cluster of processes employing such streams. Reference throughout this specification will also be made to the present invention being provided through software. However, those skilled in the art should appreciate that other applications and implementations of the invention are also envisioned.

BACKGROUND ART

Many different types of processes consume energy to obtain an output result, or to produce a required product or compound. For example, chemical or electrical processes used in manufacturing machinery and plant all consume energy, as do electrical generator systems, and also household appliances which consume energy to provide a desired result.

With large scale processes which consume significant amounts of energy, it is preferable to minimise the energy consumed where possible. In the case of, for example, electrical energy generation systems or relatively large manufacturing plant or factories, it is preferable to optimise and potentially minimise the consumption of energy through careful operation, design or reconfiguration of the plant and equipment used.

For example, in some industrial manufacturing processes, specific streams of material flows need to be supplied to different types of equipment and machinery at specific temperatures. These material flows may need to be heated or cooled from an original starting temperature to a target temperature. This in turn will require the consumption of energy to cool specific streams, and also the consumption of energy to heat specific streams.

The total energy employed to heat or cool, or total energy consumption on the whole can therefore be optimised to a global minimal level through careful placement and configuration of specific material streams with respect to one another. For example, there may be the potential for hot streams that require cooling to be placed in proximity with cold streams that require heating. Thermal energy already present in streams that needs to be removed or streams that need to have heat added can therefore be associated together to optimise the energy consumption of the process involved.

These considerations can be taken into account during what is known as an energy targeting phase and prior to design or alternatively during the reconfiguration or refitting of plant or equipment. This energy targeting phase can be used to give an approximate determination or indication of the capacity of equipment to be employed depending on estimated energy consumption requirements of the process or processes involved. The energy targeting phase involves the investigation of energy consumption of a process or processes potentially with a view to optimising same. It is preferable to consider these optimisation issues with a modelling system prior to the actual redesign, construction or modification of actual plant and equipment.

This targeting objective currently known is through the use of existing computer software. One example of this software is branded as 'Aspen Pinch' and delivered

by Aspentech of Boston, United States of America. A similar related software product also branded as 'AX-NET' is produced by Hyprotech Inc. (which has been acquired by Aspentech) is also known. Further details with respect to the particulars of these software products can also be found at the internet address – www.Aspentech.com.

In the energy targeting phase, this software allows the specific material streams of a process to be tracked, and for individual operational attributes associated with these streams to be modelled and adjusted if required. In general terms this software is normally employed to track the temperatures of specific material streams in a process. The software employed also allows for the calculation of a total energy consumed for heating (Q_h) and a total energy consumed for cooling (Q_c) for the process model.

Although this software provides a useful tool, it is not particularly flexible in application. A single value for a specific material stream attribute can only be adjusted at one time. This forces a user of the system to employ a trial and error approach through 'tweaking' particular attributes of specific streams one at a time, to hopefully arrive at an optimised value for Q_c and/or Q_h. This limitation becomes compounded and makes the software difficult to employ effectively in large scale processes which employ many material streams, where these material streams may have a number of operational attributes which can be modelled and adjusted.

An improved method, system, apparatus or computer software that addressed any or all of the above issues would be of advantage. Specifically, an improved system, software or method which allowed for flexibility in the ability of a user to input potential ranges of values or settings for the operational attributes of material streams within a process would be of advantage.

All references, including any patents or patent applications cited in this

specification are hereby incorporated by reference. No admission is made that any reference constitutes prior art. The discussion of the references states what their authors assert, and the applicants reserve the right to challenge the accuracy and pertinency of the cited documents. It will be clearly understood that, although a number of prior art publications are referred to herein, this reference does not constitute an admission that any of these documents form part of the common general knowledge in the art, in New Zealand or in any other country.

It is acknowledged that the term 'comprise' may, under varying jurisdictions, be attributed with either an exclusive or an inclusive meaning. For the purpose of this specification, and unless otherwise noted, the term 'comprise' shall have an inclusive meaning - i.e. that it will be taken to mean an inclusion of not only the listed components it directly references, but also other non-specified components or elements. This rationale will also be used when the term 'comprised' or 'comprising' is used in relation to one or more steps in a method or process.

It is an object of the present invention to address the foregoing problems or at least to provide the public with a useful choice.

Further aspects and advantages of the present invention will become apparent from the ensuing description which is given by way of example only.

DISCLOSURE OF INVENTION

According to one aspect of the present invention there is provided computer software for modelling the energy consumption of a process or cluster of processes, said process using a plurality of resource streams, with each resource stream having at least one operational attribute, said software being adapted to execute the steps of:

(i) receiving at least one set of a range of attribute values for at least one

attribute of at least one resource stream used by the process, and

(ii) calculating at least one energy consumption value for the process using said received range or ranges of attribute values.

According to a further aspect of the present invention there is provided computer software substantially as described above, wherein said software is adapted to execute the further preliminary step of:

Identifying all resource streams used within the process to be modelled.

According to yet another aspect of the present invention there is provided computer software substantially as described above, said software being adapted to execute the additional preliminary step of:

identifying all operational attributes of resource streams used within the process which affect the energy consumption of the process.

According to a further aspect of the present invention there is provided computer software substantially as described above, further characterised by the execution of the additional subsequent step of:

indicating the specific attribute value or values from the range or ranges supplied which result in the energy consumption value or values calculated.

According to a further aspect of the present invention there is provided computer software substantially as described above wherein the energy consumption value or values calculated include global minimum energy consumed to heat resource streams, and/or global energy consumed to cool resource streams.

According to yet another aspect of the present invention there is provided an energy consumption modelling system that includes a computer system

programmed with the software described above.

The present invention is adapted to provide a system, apparatus, method and/or preferably computer software to be used to model the energy consumption of a process. Those skilled in the art should appreciate the present invention may encompass specific hardware or apparatus used to implement the present invention in addition to computer software programmed into programmable logic or digital devices adapted to executed to a number of processing steps to achieve the aims of the invention.

Reference throughout this specification will in general terms be made to the present invention being implemented through computer software programmed into a computer system. However, those skilled in the art should appreciate that other implementations or aspects of the technology developed are also envisioned and reference to the above only throughout this specification should in no way be seen as limiting.

Preferably the software provided may be adapted to model the energy consumption of a particular process. In general terms, the modelling operation or facility provided can be used in investigations or analyses of specific processes and their energy consumption characteristics or requirements. In a further preferred embodiment, the model or modelling facility provided may be used to optimise the energy consumption characteristics of a process, preferably to minimise the amount of energy consumed. Reference throughout this specification will also be made to the present invention being used as a tool to optimise the energy consumption of a process, but those skilled in the art should appreciate that the present invention may also be used as a simple analytical or analysis tool if required.

Furthermore, a process as referred to throughout this specification may be defined

as any operation or set of operations which consumes energy to in turn produce a required result, or alternatively to produce a material or product. Processes can range from the domestic with the use of households hot water system and electrically powered appliances to heat, cool or mechanically process or chop materials through to the industrial, to include electricity generation systems and plant as examples. Processes that can have their associated energy consumption modelled in conjunction with the present invention may also include manufacturing plant, equipment or manufacturing production lines, or collections of production lines which may produce unrelated products or materials. Furthermore, a single process to be considered in conjunction with the present invention may also consist of or incorporate a set of sub-processes which need not necessarily be related together, nor in some instances, need not also require the physical apparatus or equipment employed to be located in close proximity or adjacent to other equipment used.

Reference throughout this specification will however be made to a process modelled in conjunction with the present invention being a single manufacturing production line for a specific type of product. However, those skilled in the art should appreciate that these references are made for the sake of simplicity only and the present invention may be applied to a wide range and number of different types of varied processes as discussed above.

The present invention may also be adapted to model energy consumption of a single process. The energy consumed may be in a variety of different forms from electrical energy, through to mechanical and thermal energy, to energy present in a magnetic field or in various types of electromagnetic radiation. However, for the sake of simplicity, reference throughout this specification will be made to the energy consumed being originally sourced from thermal energy. Again, those skilled in the art should appreciate that other types of energy may also be

monitored or modelled in conjunction with the present invention and reference to the above only throughout this specification should in no way be seen as limiting.

In addition, the energy consumed in conjunction with the present invention will in general terms be referred to as being employed to heat or cool materials. Again, however those skilled in the art should appreciate that other energy consumption applications may also be considered in conjunction with the present invention and reference to the above only should in no way be seen as limiting.

Preferably a process modelled in accordance with the present invention may include a plurality of resource streams. In general terms, a resource stream may consist of a flow of material that is consumed, modified or employed in some way within the process. For example, resource streams may consist of flows of water or other types of fluid or gases, or alternatively two or three phase flows.

Reference throughout this specification will also be made to the resource streams monitored using the present invention and employed in the particular process modelled being flows of one or more types of fluid. However, those skilled in the art should appreciate that other types of resources may also be employed and modelled in conjunction with the present invention and reference to the above only throughout this specification should in no way be seen as limiting. Furthermore, those skilled in the art should also appreciate that a resource stream need not necessarily be made up of a substantially continuous flow of material. For example, in some instances a resource stream may be composed from a supply or flow or material delivered periodically in discreet blocks if required.

In a preferred embodiment, a resource stream may have at least one operational attribute associated with it. An operational attribute may be a specific characteristic or parameter associated with a particular stream which in turn will have an effect on the energy consumed by the process modelled. Those skilled in

the art should appreciate that various different types of operational attributes may be monitored and modelled in conjunction with the present invention depending on the particular type of resource stream which the operational attribute is associated with. For example, in some instances, examples of operational attributes could include a materials temperature, flow rate, composition, pressure, latent heat of vaporization, latent heat of condensation, latent heat of sublimation and any and/or combinations of all these attributes, or flux generated by a flow of ionised particles or electrons in other instances.

In yet other embodiments the operational attribute involved may not necessarily be directly measurable or measured from the resource stream involved, but instead be derived from an effect caused by the resource stream involved. For example, such derived attributes may consist of the RPM or Revolutions per Minute of a turbine driven by a stream of super heated steam or by the combustion of a stream of hydrocarbon based fuel.

For the sake of simplicity and in general terms, reference throughout this specification will be made to the operational attributes monitored and modelled being the temperature of a fluid flow, the flow rate and the specific heat of the resource stream of a fluid flow. Again however, those skilled in the art should appreciate that other configurations and implementations of the present invention are envisioned and reference to the above only throughout this specification should in no way be seen as limiting.

In a preferred embodiment, the software employed may record, hold or otherwise receive a list of identified resource streams within a process that affect the energy consumption of the process. Preferably all the resource streams involved may be monitored and modelled in conjunction with the present invention to provide the most accurate indication or calculation of the energy consumption value or values

required.

However, in alternative embodiments it may not be necessary to identify and monitor all resource streams employed in a process. For example, in such an alternative embodiment, only a selected number of streams which are of the most importance or have the most significance with respect to energy consumption of the process may be monitored or identified. This can provide an approximate calculation of the energy consumption value or values required using relatively low cost computer systems or to provide a fast approximate indication of an energy consumption value.

In a further preferred embodiment, the software employed may calculate or recalculate an energy consumption value once it receives data associated with a new resource stream. A base line consumption value may be calculated upon entry of a single stream's data, where this value is subsequently updated each and every time a further or new stream is added to the model to be provided. This feature of the invention allows a user to clearly see which streams are of significance to the energy consumption value or values calculated.

In a preferred embodiment, all relevant operational attributes of the resource streams monitored or modelled may in turn be identified for or within the software employed. Preferably all operational attributes of the streams monitored which have an effect on the energy consumption of a process may be tracked and modelled in conjunction with a preferred embodiment of the present invention. Modelling each and every operational attribute which affects energy consumption will in turn provide an accurate calculation of energy consumption for the process modelled.

However, in alternative embodiments, each and every relevant operational attribute may not necessarily be monitored or modelled. For example, in one alternative

embodiment, only a selected number of highly relevant or highly significant attributes with respect to energy consumption may be monitored or modelled in conjunction with the present invention. The present invention can allow a rigorous check of such significance because of its interactive data entry capability that enables the calculation of the energy consumption values upon the entry of data for each resource stream. In such embodiments, the software employed may calculate and subsequently display at least one energy consumption value upon receipt of data. The energy consumption value or values calculated will then be subsequently updated every time data for a specific resource stream is added so that a user of the software can easily see which streams and associated operational attributes are of significance to the energy consumption value or values calculated. This approach can allow a fast and approximate energy consumption values to be calculated or alternatively allow the present invention to function using a relatively low capacity computer system or systems.

In a preferred embodiment, the software provided is adapted to receive at least one set of a range of attribute values from a user. The user of the software may be a person, persons or organisation wishing to model and potentially optimise the energy consumption of a particular process. The user involved can input at least one set of a range of attribute values for a selected operational attribute of a resource stream to in turn provide the base data or information required to set up a model of the process involved.

In a preferred embodiment, at least one set of a range of attribute values may be received for one or more operational attributes of a resource stream. This information can be indicative of an allowable range of values for a particular operational attribute that can vary the energy consumed by the process involved. By supplying a range of attribute values, this substantially simplifies the use of the software provided for a user, who need not experiment with each and every

potential case provided through all the discreet single values capable of being entered and received.

In a further preferred embodiment, a single set of a range of attribute values may be received from a user and assigned to each and every operational attribute identified for each and every resource stream monitored and modelled in conjunction with the present invention. The range of attribute values provided can give the operational parameters within which each of the operational attributes can vary or fluctuate in the running of a process to be modelled.

However, in alternative embodiments, a single range of attribute values need not necessarily be received for any each and every operational attribute monitored and modelled in conjunction with the present invention. For example, in some alternative embodiments, a single range of operational attributes may be provided for a single operational attribute for a resource stream that has multiple attributes, as should be appreciated by those skilled in the art. Furthermore, it should also be appreciated that more than one set of ranges of attribute values may be received in relation to a single operational attribute. Several sets of continuous ranges of attribute values may be received if required in accordance with such an embodiment.

Reference throughout this specification will however be made to the software employed receiving a single set of a range of attribute values for each and every attribute of each and every resource stream monitored and modelled in conjunction with the present invention. However, those skilled in the art should appreciate that other configurations and implementations of the software to be provided are envisioned and reference to the above only throughout this specification should in no way be seen as limiting.

In a preferred embodiment, the software provided is adapted to calculate at least

one energy consumption value using the received range or ranges of attribute values. Preferably the energy consumption value or values calculated may be an optimal value for the process involved, calculated through determining or selecting a specific collection of attribute values which result in an optimised energy consumption result.

In a further preferred embodiment, the software employed may calculate the total global minimum energy consumed by a process or a specifically optimised set of operational attribute values or settings. This calculation may then be used to fine tune the design of equipment to be employed to implement the process or alternatively to adjust or assist in redesign and redevelopment or refitting work to be completed with respect to existing process machinery.

In a further preferred embodiment, the software employed may be used to calculate a value for Q_h, being the total energy employed to heat resource streams, and Q_c, being the total energy used to cool resource streams. Q_h added to Q_c can then give the total energy consumed by the process model.

However, in an alternative embodiment the software employed may not be used to calculate minimum energy consumption values. For example, in some alternatives, the present invention may be used to calculate the maximum or worst case energy consumption values if required. In some instances, it may of advantage to model energy consumption values of a process where optimum conditions may not occur such as when, for example, the content of streams are contaminated. Forecasting or modelling potential worst case scenarios and energy consumption maximums allows the potential for overcapacity to be designed into the equipment employed.

In a preferred embodiment, the software provided is adapted to calculate global minima energy consumption values required by hot and cold resource streams in any process or cluster of processes using the following algorithmic approach.

Those skilled in the art should also appreciate that the material described below could equally well be formed to have with respect to computer pseudo code, or in high level software object code if required.

(1) The resource streams temperatures are shifted either up, in case of resource cold streams, or down, in case of resource hot streams, by half of the selected minimum temperature difference between the hot and cold resource streams. This minimum temperature difference can be selected from the temperature difference between any two streams in the model which gives a minimum value.

(2) The shifted inlet and outlet temperatures of both resource hot and cold streams are then sorted in a descending order, with duplicates removed, each successive pair representing the boundaries of a "TEMPERATURE STEP" and defining a new temperature step "S". The completion of this calculation step results in "N" number of process temperature steps.

(3) The total number of temperature steps is "N+1" where S varies from 0,1,2,...,N and the temperature step number "0" represents the external energy utility temperature step. Energy output from this external energy step have two initial values: Q0(low_output)=0.0 in "energy units" and Q0(high_output)=0.0 in "energy units"

(4) Each temperature step "S", greater than 0 where s=1,2,...,N, has energy surplus Qs(surplus). Such energy surplus have two calculated values;

Qs(low_surplus) and Qs(high_surplus). It also has energy output Qs(output) from one temperature step to another. Such energy output Qs(output) have also two calculated values;

Qs(low_output) and Qs(high_output). These values are calculated as follows for s=1,2,...,N

_Qs(low_surplus)= $(\sum_{k=1}^{n} Fcpk\_low - \sum_{j=1}^{m} Fcpj\_high)(Th,s - Tc,s)$

_Qs(high_surplus)= $(\sum_{k=1}^{n} Fcpk\_high - \sum_{j=1}^{m} Fcpj\_low)(Th,s - Tc,s)$

_Qs(low_output) = $Q_{(s-1)}(low\_output) + Q_s(low\_Surplus)$

_Qs(high_output)= $Q_{(s-1)}(high\_output) + Q_s(high\_Surplus)$

Where; ns and ms are the number of the resource hot and cold streams respectively represented in the sth temperature step and Th,s and Tc,s are the higher and lower shifted temperatures representing the boundaries and defining the temperature step.

Fcpk_low : is the low value of the flow- specific heat term resulted from the multiplication of the value of the flow F lower bound by the specific heat value cp of the hot stream number k in flow-specific heat units.

Fcpk_high : is the high value of the flow specific heat term resulted from the multiplication of the value of the flow F upper bound by the specific heat value cp of the hot stream number k in flow-specific heat units.

Fcpj_low : is the low value of the flow specific heat term resulted from the multiplication of the value of the flow F lower bound by the specific heat value cp of the cold stream number j in flow-specific heat units.

Fcpj_high : is the high value of the flow specific heat term resulted from the multiplication of the value of the flow F upper bound by the specific heat value cp of the cold stream number j in flow-specific heat units.

(5) Global minimum heating energy utility is calculated as follows:

Qh=(-1)* Minimum Qs(high_output)

Where s=0,1,2,...,N, and Qs(high_output) is the lowest value from the set of steps considered.

(6) Global minimum cooling energy utility is calculated as follows:

Qc= QN(low_out) – Minimum Qs(low_out)

Where, s=0,1,2,...,N

In a further preferred embodiment, the software provided may also be adapted to indicate the settings or values of particular operational attributes which, when used, result in the energy consumption value calculated. These particular settings or values for operational attributes may then be used in the implementation of the actual process after modelling has occurred to potentially optimise the process.

The present invention may provide many potential advantages over the prior art existing systems.

The present invention may be adapted to provide an energy consumption modelling tool which can be used with a significant degree of flexibility to calculate one or more energy consumption values. The ability to receive as inputs sets of ranges of attribute values at one time for a particular operational attribute of a resource stream greatly increases the flexibility of the software or system provided from the user's perspective. The model employed may encompass such ranges of operational attribute values to calculate using a synchronised mechanism an overall global or total minimum potential or maximum energy consumption value if required.

BRIEF DESCRIPTION OF DRAWINGS

Further aspects of the present invention will become apparent from the following description that is given by way of example only and with reference to the accompanying drawing in which:

Figure 1 shows a schematic screen shot diagram of a user interface for software provided in accordance with a preferred embodiment of the present invention.

BEST MODES FOR CARRYING OUT THE INVENTION

Figure 1 shows a schematic screen shot diagram of a user interface for software provided in accordance with a preferred embodiment of the present invention.

Figure 1 illustrates a relatively simple model of a process that incorporates four separate and distinct resource streams. Resource streams H1 and H2 are hot streams whereas resource streams C1 and C2 are cold streams.

In the situation shown, three separate operational attributes for each resource stream are monitored and modelled. The input temperature of each stream, a target or output temperature of the stream, and a flow rate (F C_p) for the stream are monitored and shown with respect to figure 1.

Figure 1 also illustrates the situation provided when a range of attribute values have been received for each attribute of each resource stream. For example, in the case of resource stream C1, a single set of a range of attribute values for input temperature have been provided, ranging from the values 297 through to 303. The same approach has also been taken with respect to all other streams and the other two operational attributes monitored.

As this information is entered, the software provided continuously updates and

calculates, under any possible minimum temperature difference between the hot and cold resources, values for both the global minimum energy required for cooling and the global minimum energy required for heating by the process employed. It also calculates both the global maximum energy required for cooling and the global maximum energy required for heating by the process employed.

Aspects of the present invention have been described by way of example only and it should be appreciated that modifications and additions may be made thereto without departing from the scope thereof.

THE UNIVERSITY OF WAIKATO

by their Attorneys

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FIGURE 1